3. Objective function

The objective function of the linear program of WinDS is to minimize the following costs:

Capital costs of new wind plants
+ Operating costs of all wind generation (including forecast/bidding penalties)
+ Cost of transmission of wind (old and new lines)
+ Cost of storing wind power
+ Capital cost of new conventional plants
+ Fuel and operating costs of conventional generation
+ Cost of spinning reserve
+ Cost of interruptible loads

In equation form with explanatory notes in [brackets]:

$$[Wind\_onshore\_capital\_\cos ts\_and\_O\&M\_\cos ts]$$

$$\sum_{c,i}(CW_c(1+cslopeW\cos tfactor*cslope_{c,i})+CWOM_c)*(\sum_{wscp}WturN_{i,wscp}*class_{c,i}+WturTN_i*classT_{c,i}+Wtur\_inregion_{c,i})$$

$$[Wind\_offshore\_shallow\_capital\_\cos ts\_and\_O\&M\_\cos ts]$$

$$+\sum_{c,i}(CWcofs_c+CWOMcofs_c)*(\sum_{wscpofs}WturNofs_{i,wscpofs}*classofs_{c,i}+WturTNofs_i*classTofs_{c,i})$$

$$[Wind\_offshore\_deep\_capital\_\cos ts\_and\_O\&M\_\cos ts]$$

$$+\sum_{c,i}(CWcofd_c+CWOMcofd_c)*(\sum_{wscpofd}WturNofd_{i,wscpofd}*classofd_{c,i}+WturTNofd_i*classTofd_{c,i})$$

$$[Cost\_to\_connect\_onshore\_wind\_to\_the\_grid]$$

$$+\sum_{i,c}Cgridconnect*(\sum_{j}WN_{i,j}*class_{c,i}+WTN_{i,j}*classT_{c,i}+\sum_{escp}Welec\_inregion_{c,escp,i})$$

$$[Cost\_to\_connect\_offshore\_shallow\_wind\_to\_the\_grid]$$

$$+\sum_{i,c}Cgridconnect*(\sum_{j}WNofs_{i,j}*classofs_{c,i}+WNofs_{i,j}*classTofs_{c,i})$$

$$[Cost\_to\_connect\_offshore\_shallow\_wind\_to\_the\_grid]$$

$$+\sum_{i,c}Cgridconnect*(\sum_{j}WNofd_{i,j}*classofd_{c,i}+WNofd_{i,j}*classTofd_{c,i})$$

$$[Wind\_transmission\_\cos t\_on\_existing\_transmission\_lines\_throughout\_analysis\_period]$$

$$+(TOWCost*dis_{i,j}+POSTSTWCOST*PostStamp_{i,j})*(\sum_{c,i,j}WN_{i,j}*class_{c,i}*CF_c+WNofs_{i,j}*classofs_{c,i}*CFcofs_c$$

$$+WNofd_{i,j}*classofd_{c,i}*CFcofd_c)*8760*PVA_{d_r,E}*(1-IWSurplusMar_{c,i\in in})$$

$$[Cost\_of\_new\_transmission\_lines\_dedicated\_to\_wind]$$

$$+TNWCost*(1+(cslope_{c,i}+cslope_{c,j})/2*cslopeT\cos tfactor)*(cpop_{c,i}+cpop_{c,j})/2*\max(50,dis_{i,j})$$

$$*\sum_{c,i,j}(WTN_{i,j}*classT_{c,i}+WTNofs_{i,j}*classTofs_{c,i}+WTNofd_{i,j}*classTofd_{c,i})$$

$$[Cost\_of\_new\_transmission\_lines\_from\_the\_wind\_site\_to\_the\_grid\_$$
$$throughout\_the\_analysis\_period]$$

$$+\sum_{c,i,wscp}(WNSC_{i,wscp}*class_{c,i}*WR2GPTS_{c,i,wscp})*CF_c*8760*PVA_{d_r,E}$$

$$[Cost\_of\_new\_transmission\_lines\_from\_the\_shallow\_offshore\_wind\_site\_to\_the\_grid\_$$
$$throughout\_the\_analysis\_period]$$

$$+\sum_{c,i,wscp}(WNSCofs_{i,wscp}*classofs_{c,i}*WR2GPTSofs_{c,i,wscp})*CFcofs_c*8760*PVA_{d_r,E}$$

$$[Cost\_of\_new\_transmission\_lines\_from\_the\_deep\_offshore\_wind\_site\_to\_the\_grid\_$$
$$throughout\_the\_analysis\_period]$$

$$+\sum_{c,i,wscp}(WNSCofd_{i,wscp}*classofd_{c,i}*WR2GPTSofd_{c,i,wscp})*CFcofd_c*8760*PVA_{d_r,E}$$

$$[[Cost\_of\_building\_new\_transmission\_lines\_to\_load\_centers\_in\_the\_same\_region\_$$
$$as\_the\_wind]$$

$$+\sum_{c,escp,j}Welec\_inregion_{c,escp,j}*MW\_inregion\_dis_{c,escp,j}*(1+cslope_{c,j}*cslopeT\cos tfactor)*cpop_{c,j}$$
$$*CF_c*8760*PVA_{d_r,E}$$

$$[Cost\_of\_building\_new\_transmission\_lines\_to\_load\_centers\_in\_the\_same\_region\_$$
$$as\_the\_shallow\_offshore\_wind]$$

$$+\sum_{c,escpofs,j}Welec\_inregionofs_{c,escpofs,j}*MW\_inregion\_disofs_{c,escpofs,j}*cpop_{c,j}*CFofs_c*8760*PVA_{d_r,E}$$

$$[Cost\_of\_building\_new\_transmission\_lines\_to\_load\_centers\_in\_the\_same\_region\_$$
$$as\_the\_deep\_offshore\_wind]$$

$$+\sum_{c,escpofd,j}Welec\_inregionofd_{c,escpofd,j}*MW\_inregion\_disofd_{c,escpofd,j}*cpop_{c,j}*CFofd_c*8760*PVA_{d_r,E}$$

$$[Cost\_of\_shortfall\_in\_failing\_to\_meet\_national\_RPS\_requirements]$$
$$+RPSSCost*RPS\_Shortfall$$

$$[Cost\_of\_shortfall\_in\_failing\_to\_meet\_state-level\_RPS\_requirements]$$
$$+\sum_{states}(ST\_RPSSCost_{states}*ST\_RPS\_Shortfall_{states})$$

$$[wind\_growth\_multiplier\_on\_wind\_capital\_\cos t]$$
$$+\sum_g CG_g*WCt_g$$

$$[wind\_installation\_growth\_multiplier\_on\_wind\_installation\_capital\_\cos t]$$
$$+\sum_{ginst}CGinst_{ginst}*WCtinst_{ginst}$$

$$[Conventional\_generators\_capital\_\cos t\_and\_fixed\_O\&M\_throughout\_the\_analysis\_period]$$
$$+\sum_{n,q}(CCONV_q + Cgridconnect + CCONVF_q)*CONVCAP_{n,q}$$
$$[Conventional\_generation\_\mathrm{var}\,iable\_O\&M]$$
$$+\sum_{n,q}CCONVV_{n,q}*(CONVGEN_{m,n,q} + CONVPGEN_{mpeak,n,q}*PCOSTFRAC_q)$$
$$[Low\_sulfur\_coal\_incremental\_\cos t]$$
$$+\sum_{n}(coallowsulinc\cos t_n * cheatrate_{coal} * PVA_{coal,d_r,E,e})*coalowsul_n$$
$$[Spinning\_reserve\_operating\_and\_fuel\_\cos t]$$
$$+\sum_{m,n,q}CSRV_{n,q}*SR_{m,n,q}*H_m$$
$$[Quick\_start\_capacity\_\cos t]$$
$$+\sum_{n,q}CQS*QS_{n,q}$$
$$[Interruptible\_load\_capacity\_\cos t]$$
$$+\sum_{n}IL_n*CILA + \sum_{i\lg,n}CIL_{i\lg}*ILt_{i\lg,n}$$
$$[Grid\_transmission\_\mathrm{var}\,iable\_\cos t]$$
$$+\sum_{m,n,p}H_m*CONVT_{m,n,p}*(TOCost*dis_{n,p} + POSTSTWCOST*PostStamp_{n,p})*PVA_{d_r,E}$$
$$[Grid\_transmission\_capital\_\cos t\_of\_new\_transmission\_lines]$$
$$+\sum_{n,p}TPCAN_{n,p}*TNCost*dis_{n,p}$$
$$[\Pr ice\_vs\_\cos t\_differential\_due\_to\_rapid\_growth]$$
$$+\sum_{tpca\_g}TPCA\_CG_{tpca\_g}*TPCA\_Ct_{tpca\_g}$$
$$[Carbon\_tax\_\cos t]$$
$$+carbtax\max*ctaxdiscsum*\sum_{m,n,q}CONVpol_{carbon,q}*H_m*(convgen_{m,n,q} + convp_{n,peak,q})*cheatrate_q$$

$$[Capital\_and\_fixed\_operating\_\cos t\_for\_storage\_conversion\_at\_a\_wind\_site]$$
$$+(CCH2_{electrolyzer}+CfixOMH_{electrolyzer}*PVA_{d_r,E})*\sum_i ELE_i$$
$$[Variable\_\cos t\_throughout\_the\_analysis\_period\_for\_storage\_conversion\_at\_a\_wind\_site]$$
$$+CAOMH_{electrolyzer}*(\sum_i hfs_i+\sum_{c,hscp,i} hf\_inregion_{c,hscp,i}+(\sum_{c,i,s} fcell\_inregion_{c,i,s}+\sum_{i,r,s} fcell_{i,r,s})/CHEFF_{fuelcell})$$
$$[Capital\_\cos t\_of\_storage\_at\_a\_wind\_site;\_storage\_sized\_for\_one\_summer\_day's\_throughout]$$
$$+CCH2_{storageatwind}*\sum_i h2stored\_summerday_i$$
$$[Storage\_at\_wind\_\mathrm{var}iable\_and\_fixed\_O\&M\_\cos t\_throughout\_the\_analysis\_period]$$
$$+(CAOMH_{storageatwind}+CfixOMH_{storageatwind}*PVA_{d_r,E})*(\sum_{c,i,s} fcell\_inregion_{c,i,s}+\sum_{i,r,s} fcell_{i,r,s})/CHEFF_{fuelcell}$$
$$[Cost\_to\_transport\_H2\_fuel\_from\_a\_wind\_farm\_to\_a\_city\_gate\_within\_the\_same\_region]$$
$$+\sum_{c,hscp,j}(hf\_inregion_{c,hscp,j}*hf\_inregion\_\cos t_{c,hscp,j})*PVA_{d_r,E}$$

$$[Capital\_\cos t\_and\_fixed\_operating\cos t\_of\_fuel\_cell\_at\_wind\_site]$$
$$+(CCH2_{fuelcell}+CfixOMH_{fuelcell}*PVA_{d_r,E}*\sum_i Fcellcapacity_i$$
$$[Variable\_O\&M\_\cos t\_throughout\_the\_analysis\_period\_of\_Fuel\_cell\_a\bar{t}\_wind\_site]$$
$$+CAOMH_{fuelcell}*(\sum_{c,i,s} fcell\_inregion_{c,i,s}+\sum_{i,r,s} fcell_{i,r,s})$$
$$[H2\_fuel\_transport\_\mathrm{var}iable\_and\_fixed\_O\&M\_\cos t\_throughout\_the\_analysis\_period\_$$
$$for\_H2\_from\_wind]$$
$$+(CAOMH_{h2transportation}*dis_{i,j}+CfixOMH_{h2transport}*PVA_{d_r,E})*\sum_{i,j} hf_{i,j}$$
$$[Cost\_adder\_for\_grid\_electricity\_\sup plied\_to\_electrolyzers\_at\_wind\_farms]$$
$$+\sum_{i,m}(grid\_2\_welectrolysis_{i,m}+grid\_2\_welectrolysis\_inregion_{i,m})*ind\_elec\_adder*PVA_{d_r,E}$$

$$[Distributed\_fuel\_cell\_capital\_\cos t\_and\_fixed\_O\&M]$$
$$+\sum_n DISFCELL\_CAP_n*(CCH2_{fuelcell}+CfixOMH_{fuelcell}*PVA_{d_r,E})$$
$$[Distributed\_fuel\_cell\_and\_storage\_\mathrm{var}iable\_O\&M\_\cos t]$$
$$+\sum_{j,m} hfdiselec\_2\_fcell_{j,m}*(CAOMH_{fuelcell}+CAOMH_{storageatcity})$$
$$[Storage\_at\_city\_capital\_\cos t\_and\_fixed\_O\&M]$$
$$+(\sum_{j,m} hfdiselec\_2\_fcell_{j,m}/summerdays)*(CCH2_{storageatcity}+CfixOMH_{storageatcity}*PVA_{d_r,E})$$

$$[Steam\_methane\_reformer\_capital\_\cos t\_plus\_fixed\_O\&M\_\cos t\_throughout\_the\_analysis\_period]$$

$$+(CCH2_{ngreformer}+CfixOMH_{ngreformer}*PVA_{d_r,E})*\sum_j HF\_STEAMREF\_CAP_j$$

$$[Steam\_methane\_reformer\_\mathrm{var}iable\_O\&M\_\cos t\_and\_natural\_gas\_\cos t\_throughout\_the\_analysis\_period]$$

$$+\sum_j hfsteamref_j*(CAOMH_{ngreformer}+Fprice_{gascc}*PVA_{gas.j,d,E}/CHEFF_{ngreformer})$$

$$[Distributed\_electrolyzer\_capital\_\cos t\_and\_fixed\_O\&M\_\cos t\_throughout\_the\_analysis\_period]$$

$$+\sum_j HF\_DISELEC\_CAP_j*(CCH2_{distributedelectrolyzer}+CfixOMH_{distributedelectrolyzer}*PVA_{d_r,E})$$

$$[Distributed\_electrolyzer\_\mathrm{var}iable\_O\&M\_\cos t\_and\_industrial\_electricity\_adder\_throughout\_the\_analysis\_period]]$$

$$+(\sum_j hfdiselec_j+\sum_{j,m} hfdiselec\_2\_fcell_{j,m})*(CAOMH_{distributedelectrolyzer}+ind\_elec\_adder/CHEFF_{distributedelectrolyzer}*PVA_{d_r,E})$$

$$[Value\_of\_hydrogen\_produced]$$

$$-H2PRICE*(\sum_{c,hscp,i} hf\_inregion_{c,hscp,i}+\sum_i hfd_i+\sum_i hfdiselec_i+\sum_i hfsteamref_i)*PVA_{d_r,E}$$

$$[carbon\_emissions\_\cos t]$$

$$+carbtax\max*ctaxdiscsum*steam\_ref\_emiss_{pol}*\sum hfsteamref_j/CHEFF_{ngreformer}$$

$$[Electrolyzer\_growth\_multiplier\_on\_electrolyzer\_capital\_\cos t]$$

$$+\sum_{hebp} CGelectrolyzer_{hebp}*HEGBIN_{hebp}$$

$$[Steam\_methane\_reformer\_growth\_multiplier\_on\_SMR\_capital\_\cos t]$$

$$+\sum_{hsmrbp} CGSMR_{hsmrbp}*HSMRGBIN_{hsmrbp}$$

$$[Fuel\_cell\_growth\_multiplier\_on\_fuel\_cell\_capital\_\cos t]$$

$$+\sum_{hfcbp} CGFC_{hfcbp}*HFCGBIN_{hfcbp}$$

Where:

E is the evaluation period (years) over which all investments are considered

$\mathbf{CW_c}$ is the capital cost of class c wind ($/MW) (see equation in Financial Parameters section)

$\mathbf{cslope_{c,i}}$ is the average slope of the terrain at class c sites in region i

cslopeWcostfactor is the fractional increase in wind capital cost per degree of topographical slope

cslopeTcostfactor is the fractional increase in new transmission line capital cost per degree of topographical slope

$\mathbf{CWOM_c}$ is the present value over the evaluation period (E) of the operating costs (variable and fixed) for a class c wind machine ($/MWh for E years) (see equation in Financial Parameters section)

$\mathbf{CWOMcofs_c}$ is the present value of E years of fixed and variable operating costs for class c shallow offshore wind including production tax credits

$\mathbf{CWOMcofd_c}$ is the present value of E years of fixed and variable operating costs for class c deep offshore wind including production tax credits

$\mathbf{class_{c,i}}$ is the binary parameter that indicates whether class c onshore wind in region i that uses existing (at the start of the analysis time frame) transmission is the best onshore wind to consider in this time period

$\mathbf{classT_{c,i}}$ is the binary parameter that indicates whether class c onshore wind in region i that uses new (installed in this time period) transmission is the best onshore wind to consider in this time period

$\mathbf{classofd_{c,i}}$ is the binary parameter that indicates whether class c deep offshore wind in region i that uses existing (at the start of the analysis time frame) transmission is the best deep offshore wind to consider in this time period

$\mathbf{classofs_{c,i}}$ is the binary parameter that indicates whether class c shallow offshore wind in region i that uses existing (at the start of the analysis time frame) transmission is the best shallow offshore wind to consider in this time period

$\mathbf{classTofd_{c,i}}$ is the binary parameter that indicates whether class c deep offshore wind in region i that uses new (installed in this time period) transmission is the best deep offshore wind to consider in this time period

$\mathbf{classTofs_{c,i}}$ is the binary parameter that indicates whether class c shallow offshore wind in region i that uses new (installed in this time period) transmission is the best deep offshore wind to consider in this time period

Cgridconnect is the cost of the substation and other expenses related to connecting to the grid, not including any transmission line builds ($/MW)

TOCost is the cost for wind to use existing transmission lines ($/MWh-mile)

TNCost is the cost of new transmission lines ($/MW-mile)

TNWCost is the cost to build a new transmission line ($/MW-mile)

TOWCost is the cost of wind transmission on existing lines ($/MWh-mile)

$\mathbf{WR2GPTSofd_{c,i,wscpofd}}$ is the cost ($/MW) of building transmission interconnect to the grid for class c deep offshore wind resource in region i in supply curve step wscpofd

$\mathbf{WR2GPTSofs_{c,i,wscpofs}}$ is the cost ($/MW) of building transmission interconnect to the grid for class c shallow offshore wind resource in region i in supply curve step wscpofs.

$dis_{i,j}$ is the distance between wind supply region i and demand region j (miles)
POSTSTWCOST is the cost to transmit into or across a PCA on existing transmission lines ($/MW-PCA)
$PostStamp_{i,j}$ is the number of PCAs that must be crossed to transmit from wind supply region i to demand region j
CF_c is the capacity factor for new onshore wind at a class c site
$CFcofd_c$ is the annual capacity factor of new deep offshore wind systems of class c in the time period being run
$CFcofs_c$ is the annual capacity factor of new shallow offshore wind systems of class c in the time period being run
$MW\_inregion\_dis_{c,escp,j}$ is the levelized cost from the escp step of the supply curve for the cost of building a transmission line within region i from a class c onshore wind site to a load center
$MW\_inregion\_disofd_{c,escpofd,j}$ is the levelized cost from the escpofd step of the supply curve for the cost of building a transmission line within region i from a class c deep offshore wind site to a load center
$MW\_inregion\_disofs_{c,escpofs,j}$ is the levelized cost from the escp step of the supply curve for the cost of building a transmission line within region i from a class c shallow offshore wind site to a load center
RPSSCost is the penalty imposed on utilities for not meeting the national RPS requirement
RPS_Shortfall is the variable for the additional amount of wind generation needed to meet the national RPS requirement beyond that supplied
$ST\_RPSSCost_{states}$ is the penalty imposed on utilities for not meeting the RPS requirement in "states"
$ST\_RPS\_Shortfall_{states}$ is the variable for the additional amount of wind generation needed to meet the RPS requirement beyond that supplied in "states"
$IWSurplus_{c,i,in}$ is the fraction of wind from a class c site in region i that is supplied to interconnect in that cannot be used because there is excess generation (see Wind Intermittency Parameters section)
$cpop_{c,i}$ is a multiplier on the capital cost of transmission lines for wind to account for increased siting/land costs in highly populated areas. The value varies between 1 and 2 as a linear function of population density in the vicinity of class c wind sites in region i.
$WR2GPTS_{c,i,wscp}$ is the cost to build transmission from the class c wind site in region i to the closest available grid transmission capacity ($/MW) (see Appendix D, GIS Calculations.)
$CCH2_{technology\ name}$ is the capital cost of the storage (hydrogen) technology ($/MW or $/unit stored energy)
$CAOMH_{technology\ name}$ is the present value over the evaluation period of the variable operating cost (including any production tax credit) of the storage (hydrogen) technology ($/MWh or $/unit stored energy)
$CfixOMH_{technology\ name}$ is the fixed operating cost of the storage (hydrogen) technology ($/MW-yr or $/unit stored energy)
$CHEFF_{technology\ name}$ is the efficiency of the storage (hydrogen) technology (units out/units in)

hf_inregion_cost$_{c,hscp,j}$ is the cost associated with step hscp for the shipment of hydrogen from a class c wind site within region i to a city within the region

ind_elec_adder is the additional cost beyond the wholesale cost for delivering grid electricity to distributed electrolyzers and electrolyzers at the wind site

h2stored_summerday$_i$ is storage (e.g., hydrogen storage) capacity required to meet the on-peak operation of the fuel cells at wind sites in region i

H2PRICE is the price that hydrogen will receive in the marketplace in this time period

H2energy is the annual production of energy for storage (e.g., hydrogen storage)

$$h2energy = (\sum_{s,i,r} fcell_{s,i,r} + \sum_{i,c,s} fcell\_inregion_{i,c,s}) / CHEFFfuelcell$$

H2energy_summerday is the energy produced for storage (e.g., hydrogen storage) during a summer day

$$h2energy\_summerday = (\sum_{i,r} fcell_{summer,i,r} + \sum_{i,c} fcell\_inregion_{i,c,summer}) / CHEFFfuelcell / (numhourssummer / 24)$$

where **numhoursummer** is the number of hours in June – August

summerdays is the number of days in the summer (= numhoursummer/24)

carbtaxmax is the ultimate carbon tax level once the tax has been fully phased in ($/ton carbon)

ctaxdiscsum is the multiplier to convert annual cost of carbon to present value cost over the evaluation period

CGelectrolyzer$_{hebp}$ is the difference between the price and cost of the technology for converting power to stored energy in growth bin hebp ($/MW)

CGfuelcell$_{hfcbp}$ is the difference between the price and cost of the technology for converting stored energy to power in growth bin hfcbp ($/MW)

TPCA_CG$_{tpca_g}$ is the difference between the price and cost of transmission in transmission growth bin tpca_g ($/MW-mile) (see the Financial Parameters section)

CG$_g$ is the increase in turbine price over cost in growth bin g due to rapid growth in wind deployment ($/MW) (see the Financial Parameters section)

CGinst$_{ginst}$ is the increase in wind installation price over cost in growth bin ginst, due to rapid growth in wind deployment ($/MW) (see the Financial Parameters section)

H$_m$ is the number of hours in a year in time slice m

CCONV$_q$ is the present value of the revenue required to pay for the capital cost of one MWof capacity of generating technology q ($/MW) including interest during construction, finance and taxes (see the Financial Parameters section)

CCONVF$_q$ is the present value over the evaluation period of the fixed operating costs for conventional technology q ($/MW-yr) (see the Financial Parameters section)

CCONVV$_{n,q}$ is the present value over the evaluation period of the variable operating and fuel costs for conventional technology q in PCA n ($/MWh) (see the Financial Parameters section)

PCOSTFRAC$_q$ is the multiplier on the operating costs of technology q for use as a peaker (i.e. when the generation in the diurnal peak period exceeds the average generation in the diurnal shoulder periods)

coallowsulincost$_r$ additional cost of low-sulfur coal (relative to high-sulfur coal) ($/Mbtu)

Ecostescal$_{n,q}$ is the annual real price escalation of fuel used in PCA n by technology q

cur_year is the calendar year of the last year of the current 2-year period
cheatrate$_q$ is the heat rate for technology q (MBTU/MWh)
PVA$_{name,d,E,n}$ is the present value factor for fuel for technology q in PCA n escalating over time (see derivation in the Financial Parameters section)
CONVpol(pollutant)$_q$ is the emissions of pollutant (pounds per MWh)
Carboncost is the cost of carbon emissions ($/pound carbon)
CCT$_{n,p}$ is the present value over the evaluation period of the cost per MWh of transmission between PCAs n and p ($/MWh) (see the Financial Parameters section)
CSRV$_{n,q}$ is the present value over the evaluation period of the cost of spinning reserve in PCA n ($/MW-hour) of type q (see the Financial Parameters section)
CIL$_n$ is the present value over the evaluation period of the base cost of interruptible load in PCA n ($/MWh)
CIL$_{ilg}$ is the present value over the evaluation period of the cost of interruptible load in bin ilg ($/MWh), i.e. of higher levels of interruptible load use.
CQS is the cost to modify a generation plant for fast-start-capability to provide additional operating reserve ($/MW)